Survey Galaxies in Virgo

Finding the Virgo Cluster

Our Milky Way galaxy is a member of a sparse Local Group of galaxies that are close (on a cosmological scale) to the much richer Virgo Cluster. About 40 to 80 million light years away from us, in a direction not far from the autumnal equinox in Virgo, there is a region of the sky containing over a thousand galaxies. This cluster covers over 10° of sky, 20 times the apparent diameter of the full Moon!

You can explore a zoomable image of the Virgo cluster provided by the European Southern Observatory at this link:

http://www.eso.org/public/images/eso0919c/zoomable/ [1]

and read about it on Wikipedia:

http://en.wikipedia.org/wiki/Virgo_Cluster [2]

To appear so large at such a great distance it must extend across several million light years of space. This is one of nearly a thousand such clusters of galaxies that are known; it is the nearest one of significant size. Galaxies in this cluster are separating from us at speeds of around 1200 km/sec. This means that in the time it took you to read this paragraph, we moved away from the Virgo cluster by more than the diameter of the Earth.

We also measure how the Milky Way is moving with respect to the large scale distribution of matter in the universe by observing light left over from the Big Bang, the cosmic background radiation. From such measurements we have discovered that while galaxies in our Local Group are moving away from the galaxies in the Virgo Cluster at 1200 km/sec, we are being drawn at 600 km/sec toward an unseen Great Attractor that lies beyond it.

The Virgo Cluster is therefore an extremely important outpost for cosmological exploration. It is close enough that, with the Hubble Space Telescope, we are able to resolve individual stars in its galaxies. It participates in the Hubble Law expansion, yet it also is influenced by the gravitational pull of our Local Group and other masses in our part of the universe. In addition, it contains some galaxies that are extremely interesting in their own right.

To find the Virgo Cluster, begin by looking on the web:

http://www.sky-map.org/ [3]

This link opens a new window to the Sky-Map web site. Enter "Virgo Cluster" in its search box and click on the Sky-Map magnifying glass to see about 1 degree of the sky centered on the cluster.

The map displays astronomical coordinates in the upper right. Locate 12h 24 min in right ascension, the celestial coordinate equivalent to longitude on the Earth, and about 8° in declination, the coordinate equivalent to latitude on Earth. This will center the field on Messier 49 (M49).

Adjust the zoom on the display so that you see about 20° of sky. You may turn on the constellation markers by clicking the icon for constellations on the upper left of the Sky-Map page. There is an alternate version of the page that is sometimes easier to use that comes up when you click the "mouse" icon on the main page, or by using this link that takes you directly to the cluster on the map:

Sky-Map of the Virgo Cluster [4]

1. What constellation is this? Name another constellation that borders it. (Hint: in Sky-Map when you move the cursor over an object an information box will appear that describes it and offers additional links.)

2. During what month of the year would this region of the sky be most visible, no matter where you are on Earth? (Hint: Virgo is near the autumnal equinox, where the Sun is at the beginning of autumn in the northern hemisphere.)

The Palomar Sky Survey

Between 1949 and 1956, a 1.2-meter diameter Schmidt camera on Palomar Mountain was used to survey the entire sky visible from a low latitude in the continental United States. Sponsored by Palomar Observatory and the National Geographic Society, the resulting set of 900 pairs of photographs are still a widely used reference in astronomical research. Each image covers a useful field about 6° across allowing for overlap so that the edges are photographed twice. The sky was photographed once in blue light to capture hot stars and dusty nebulae, and again in red light to show cool stars and gaseous nebulae. Originally, paper copies of the original glass plates were distributed to observatories around the world where astronomers used them to identify objects for more detailed study. Most large telescopes have such a small field of view that they can look only at one thing of special interest at a time, whereas the Schmidt camera has a large field of view, almost big enough to capture the entire Virgo cluster in one image. With the development of digital image technology and the capacity to store enormous quantities of data, it is also possible to automate mapping the entire sky, and to reconstruct the needed wide field views from many small individual images. Now, imaging databases recorded in visible light, x-rays, and in the infrared, are available in digital form over the Internet, providing astronomers with access to a virtual telescope from their desktop. The background images of the sky in Sky-Map and in Google-Sky are from the Palomar Sky Survey and its successors. Recent images such as the one below taken by an amateur astronomer are nearly as good.

Virgo Cluster with north up and west to the right. Click the image for a closer view. (Credit: Robert Gendler [5])

M87

Let's start with M87. It is one of the largest galaxies in the cluster, and it is fairly easy to find on the images. Near the center of this picture it seems to be an isolated round object. That's the galaxy you want, south and west of the simlar looking pair of galaxies M84 and M86. In Sky-Map when you run the cursor over a galaxy you'll see an identifcation box with more information.

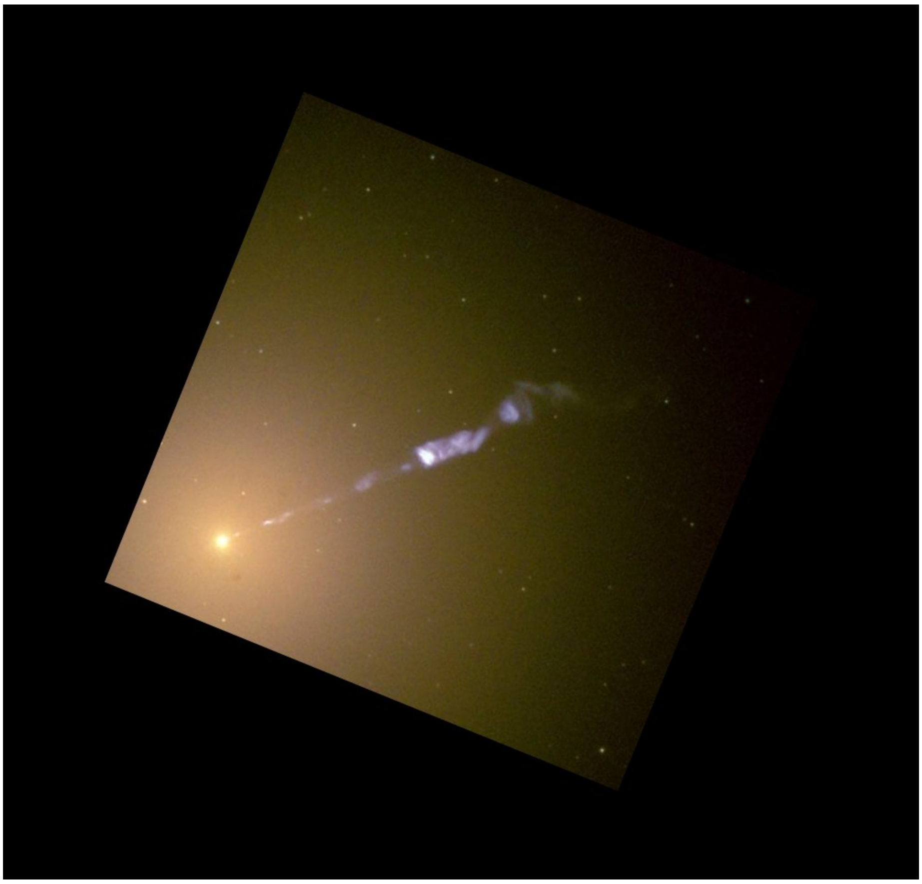
You can zoom out a little from the close view that a search will provide to see where M87 is in the cluster. Or, you can zoom in to see a more detailed image. A left click will bring up images from the Hubble Space Telescope and other sources.

The M in these names stands for Messier, after Charles Messier, the French comet hunter nicknamed Cometferret, who made a comprehensive list of the brightest non-stellar objects in the sky. There are 103 objects on this list that he discovered himself, and 109 altogether including others he confirmed. His work on the catalog was largely complete by 1789 and the time of the French Revolution. Messier, who died in 1817 at age 86, was a contemporary of William Herschel, the discoverer of Uranus.

The first object on Messier's list is M1, the Crab Nebula. It is a remnant of a supernova in Taurus that he found in 1758. The galaxies in Virgo were all found much later, probably because observing faint objects is difficult when they are low in the sky, as this cluster of galaxies is when seen from Paris.

M87 in a image from the Kitt Peak 4-meter telescope. (Credit: NOAO)

M87 in a short exposure image with a 0.5 meter telescope at Kitt Peak. (Credit: NOAO)



M87 as seen with the Hubble Space Telescope. The jet is matter being ejected by the central black hole. (Credit: NASA)

Look closely at theses images of M87. Compare them with various types of galaxies illustrated in books and on the web. Try to see how this galaxy fits in the classification scheme devised by Edwin Hubble.

Now go back and look again at the large image of the Virgo Cluster above, or explore the region with Sky-Map, and you'll see lots of other similar galaxies. The most common kind of galaxy in a cluster like Virgo is elliptical.

In the Hubble classification, the number following E indicates just how elliptical the galaxy appears. It should be obvious that M87 is an elliptical galaxy. The ratio of the long dimension a to the short dimension b is used to tell just how elliptical the galaxy is, according to 10(a-b)/a, so if b and a are the same it is E0, and if b is 30 percent of a it is E7.

3. Estimate the large and small dimensions for M87 and calculate 10(a-b)/a. How elliptical is it? This is the number after "E" in the classification.

Hints: A simple way to do this is with a millimeter scale on a ruler. Hold it up to the screen and measure across the galaxy's long (a) and short (b) dimensions. Calculate the ratio (a-b)/a and multiply by 10. You can also do this in Sky-Map, reading the coordinates and converting to seconds of arc. Since the galaxy is not oriented north-south or east-west, finding the long and short dimensions this way requires more math skills than simply measuring with a ruler.

If you look at the detailed images of M87 again, you should be able to see many apparently tiny fuzzy dots all around it. Each of these "dots" is a spherical cluster of hundreds of thousands of stars. Similar globular star clusters surround our Milky Way.

There are about 2000 such globular clusters with M87, but only about 100 around the Milky Way. The halo of clusters around this galaxy help to define its size. Return to M87 on Sky-Map and measure the diameter of the halo in seconds of arc. You can do this by using the coordinate readout that changes as you move the cursor around the image. Declination (north and south) is indicated in degrees, minutes, and seconds of arc. Right Ascension (east and west) is measured in hours, minutes, and seconds of time. Each second of time is 15 seconds of arc.

4. How large in seconds of arc is the image of M87 and its halo of globular clusters?

Hints: Look at the declination reading in Sky-Map for the center of the galaxy and for a point just beyond the halo north of the galaxy center so that right ascension is the same as at the center. The difference in declination readings will give you the radius of the halo. Remember that 1 degree is 60 arcminutes, and 1 arcminute is 60 arcseconds. The diameter is twice the radius.

To give you a sense of its true size, let's convert this measurement into a diameter in light years. The angle that you see in the sky is determined by the distance to the galaxy, and its real size. Something quite large (like this galaxy) will appear to be very small simply because it is far away. Mathematically, we say that

$$S = A\,R / 206{,}000$$

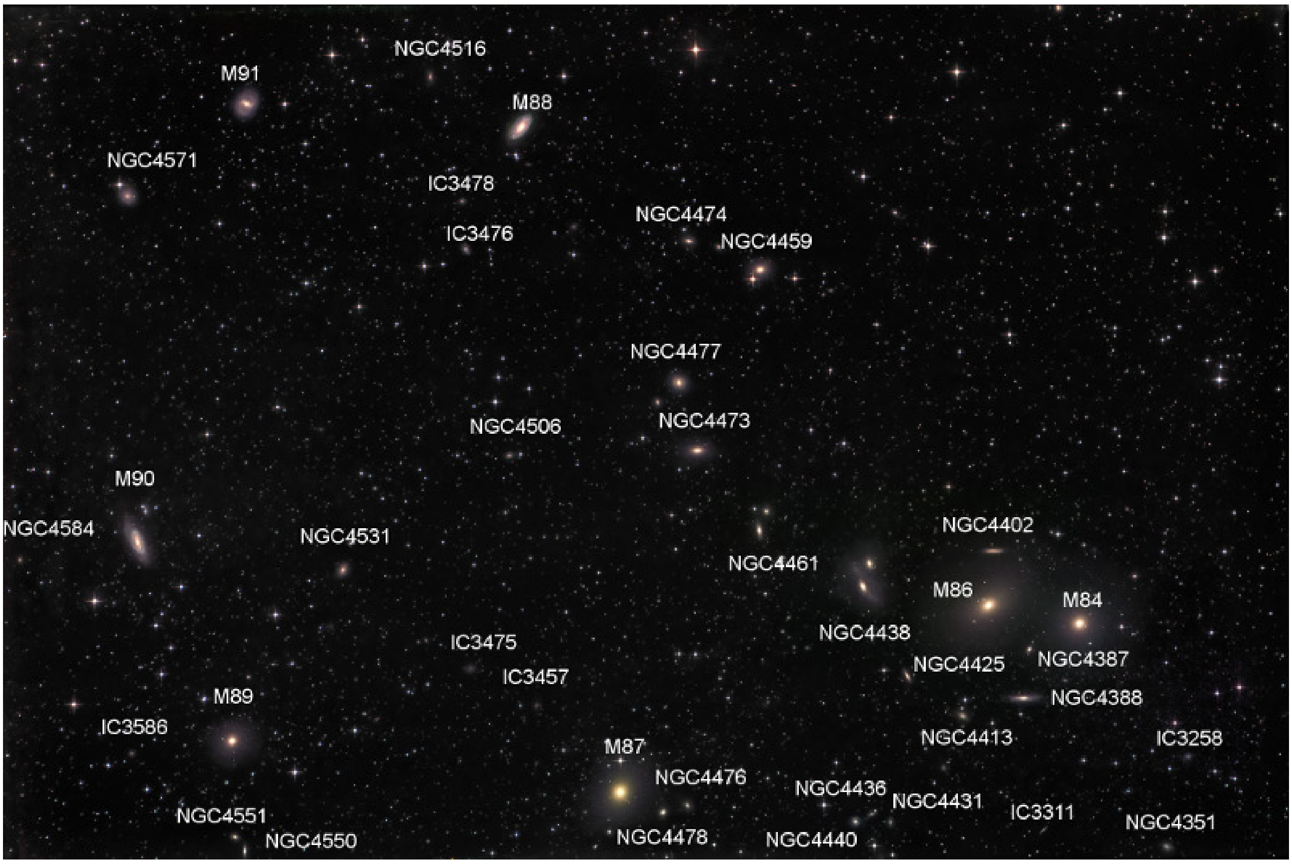
where S is the real size, R is the distance, and A is the angle in seconds of arc. In this formula both S and R have the same units. The 206,000 converts from seconds of arc to radians. Assume that the galaxy is 60,000,000 light years away (R=60,000,000) and calculate how large it must be in light years to appear to be the size you measured.

5. How large is M87 in light years? Compare to the Milky Way which with its halo is about 130,000 light years in diameter.

M84 and M86

Above and to the right of M87 are the two other elliptical galaxies, M84 and M86. To find them in Sky-Map, start at M87 and work your way over, or simply type M84 in the search box. They are hard to miss, since they look so much like M87.

These galaxies are also known by their NGC numbers, an acronym that stands for New General Catalog [6]. Almost all nearby galaxies and non-stellar objects are listed in this catalog and its supplements. M87 is known as NGC 4486; M84 is NGC 4374; and M86 is NGC 4406. Most astronomers use NGC numbers whenever they can to identify the objects that they are working on.



Virgo Cluster with galaxies labeled. Click for a larger version. (Credit: Robert Gendler)

How many E's?

There are no large elliptical galaxies in the local group, but obviously there are many in the Virgo Cluster. In order for you to see the whole cluster in detail you will need to explore a field several degrees across.

Begin with M84, M86, and M87. Take a few minutes to get oriented, but once you have scanned around this region you'll notice just how many galaxies there are over the entire cluster. The Virgo cluster spans a field several degrees across the sky.

You should also notice that not all the galaxies you see are elliptical. There are many that are definitely spiral. Although some of the spirals are overexposed, and may be hard to distinguish from ellipticals, if you see a hint of an arm sticking out, it is a spiral. Otherwise it is probably elliptical. Also, elliptical galaxies are never seen flatter than E7, so if it is really oblong or disk shaped, even if you cannot see spiral arms on this image, it is probably a spiral. Some bright stars can look like E0 galaxies. Look for a soft edge to the image characteristic of the galaxy. Stars have very sharply defined disks. Zoom out so that you are seeing a field about 2 degrees across.

6. Stay within 2 degrees across north-south (declination) and 8 minutes across east-west (right ascension) and survey the field for elliptical galaxies. There are many, although most are small by comparison to M87. How many do you see that are similar to M87 in size?

Looking for Spirals

Most of the other galaxies in the cluster are spiral. All but 2 percent of galaxies fall somewhere in the Hubble classification scheme which includes normal elliptical and spiral galaxies.

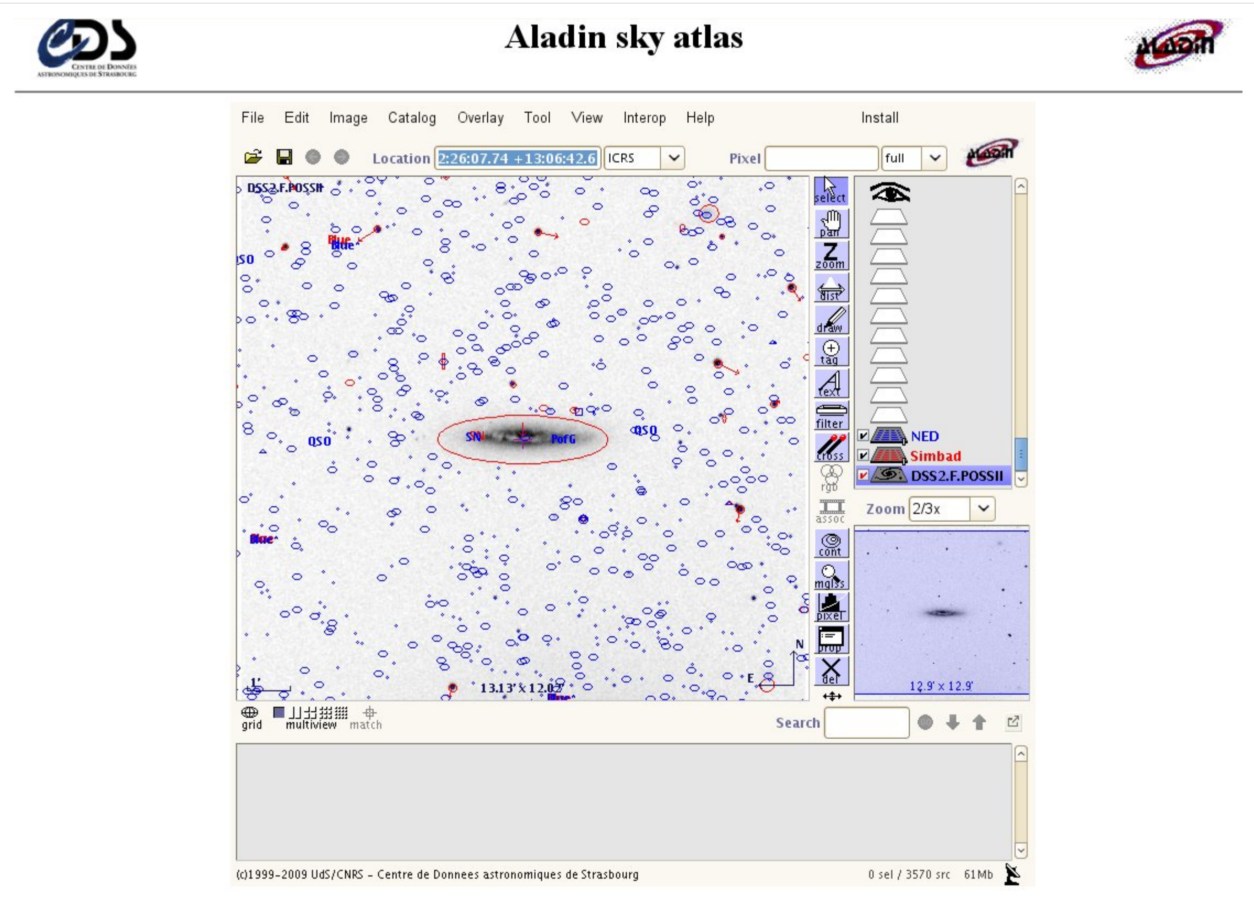
Find what you think are the three largest spiral galaxies in the Virgo Cluster. The galaxies are usually identified by their NGC number since Messier's catalog does not include most of the galaxies in the Virgo cluster. You can use the labeled image above to help identify what you find, or the cursor labels in Sky-Map.

7. What are the 3 largest spiral galaxies in the Virgo Cluster? Give their NGC or Messier catalog names, and their right ascension and declination.

You may use Aladin to see selected regions of the Sky Survey in detail. Click the link below to start Aladin in a separate window:

Aladin sky atlas [7]

Once it has started (it is a large file and takes a while), note the Command/Location window at the top of Aladin's display. You can type an object name or coordinates into this window and it will find images and catalog entries for you from the digital sky surveys and other data bases. The images will be in different layers that you can turn on or off by clicking on the upper right panel where the layers are named. Usually a query will produce an image from the digital sky survey (with a name like DSS), and entries from Simbad and NED, the catalog database and another listing of faint galaxies. Here's what it will look like if you enter NGC4402 in the Command/Location window.



NGC4402 in Aladin

You can enter the name or the coordinates. If you enter a name, Aladin tries to identify its coordinates and then will put the coordinates back into the location box. As you move the cursor around the field the location box will update and tell you the celestial coordinates. You can even use these same coordinates to see the view in Sky-Map.

One of the large spirals in the Virgo cluster is a barred spiral, a type SB galaxy. See if you can identify which one this is by the appearance of a "bar" rather than a tight pinwheel of spiral arms toward the center.

8. Find a large barred spiral in the Virgo cluster and identify it by its NGC number and its celestial coordinates.

Interacting Galaxies

Southeast of M87 (NGC 4486), just off the pictures above, there is a pair of spiral galaxies that seem to be colliding. Use Sky-Map to find them. (Hint: NGC4564 , at 12h36m27s and +11°26'11", is just north of the colliding pair.)

There is a cross reference to catalogs called "Simbad" that will do a search by coordinates

SIMBAD Astronomical Database [8]

and you may use it to identify an object by coordinates. Click on the link above and when it opens select "by coordinates" and enter the coordinates of NGC4564. It will return a list of many galaxies around the coordinates you entered. NGC4564 will be close to the top of the list. If you click on its entry under "Identifier" you will get back specific information about the "Galaxy in a group of galaxies", as Simbad calls it. For example it will tell you that the "radial velocity" of NGC 4564 (astronomers call it cz) is 1132.9 km/s. Sky-Map links to this database too when you left-click on an object.

9. Identify the two interacting galaxies, give their celestial coordinates in right ascension and declination from Sky-Map, and describe them.

There are excellent simulations [9] of colliding galaxies available from astronomers who are modeling what happens when two galaxies pass through one another. These are real gravitational simulations, with stars following paths based on the physics of gravity and colliding gas and dust. Watch what happens to the galaxies, and notice all the different new forms that appear as galaxies interact with one another. Spiral galaxies may owe their existence to collisions in clusters of galaxies.

How large is the Virgo cluster?

As you look over these images you'll see lots of galaxies. Most of them are in the Virgo cluster. Some are not, of course, because it is possible to see through the Virgo cluster to more distant clusters. In fact, the overlays from "NED" that appear in Aladin are mostly the ones at greater distance. But to get a rough estimate of how many galaxies there are in this cluster, just start counting the obvious ones ...

10. How many objects do you see in Sky-Map within 10 degrees across north-south and 40 minutes across east-west of M87 that are definitely galaxies, not stars?

If we take 10 degrees as the diameter of the Virgo cluster, then at a distance of 60 million light years, the whole thing is nearly 10 million light years across. This is 5 times the size of the Local Group. The Andromeda Galaxy and the Milky Way galaxy, two of its largest members, are separated only by 2 million light years. The Virgo Cluster is larger in diameter and has more members than our own Local Group.

References

[1] http://www.eso.org/public/images/eso0919c/zoomable/
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